MYCOTAXON

ISSN (print) 0093-4666 (online) 2154-8889 © 2016. Mycotaxon, Ltd.

January–March 2016—Volume 131, pp. 61–85

http://dx.doi.org/10.5248/131.61

Some stromatic pyrenomycetous fungi from northern Thailand — 2. *Annulohypoxylon* and *Ustulina*

Larissa N. Vasilyeva[1*], Steven L. Stephenson[2] & Kevin D. Hyde[3,4]

[1]*Institute of Biology & Soil Science, Far East Branch of the Russian Academy of Sciences, Vladivostok 690022, Russia*

[2]*Department of Biological Sciences, University of Arkansas, Fayetteville, Arkansas 72701, USA*

[3]*Institute of Excellence in Fungal Research &* [4]*School of Science, Mae Fah Lung University, Chiang Rai 57100, Thailand*

[*] Correspondence to: *vasilyeva@biosoil.ru*

Abstract—Fourteen species of *Annulohypoxylon* and one species of *Ustulina* collected in northern Thailand are discussed. Only three of the species (*Annulohypoxylon bahnphadengense*, *A. bogoriense* comb. nov., *A. urceolatum*) have been reported previously from southeastern Asia. The other twelve species (*A. chiangmaiense*, *A. derelictum*, *A. dipterocarpi*, *A. maesaeense*, *A. microbovei*, *A. morisuspectum*, *A. neglectum*, *A. paratruncatum*, *A. planodiscum*, *A. pseudonitens*, *A. sordidum*, *Ustulina pseudozonata*) are proposed as spp. nov., described, and illustrated.

Key words—*Ascomycota*, taxonomy, *Xylariaceae*

Introduction

In our first paper in this series (Vasilyeva et al. 2012), we emphasized that Thailand is the portion of the Indo-Malayan center of biodiversity characterized by a unique assemblage of vascular plants and, consequently, many associated species of fungi. As numerous xylariaceous fungi are host-specific (Rogers 1979, Whalley 1985, 1996, Stadler 2011) and those within the Indo-Malayan center of biodiversity would be expected to be likewise, it can be difficult to trace host-fungus associations in tropical forests, where dead branches are mixed together on the forest floor and the tree (or trees) from which they have fallen are not easy to identify. Nonetheless, we anticipate that future research will reveal definite substrate preferences for southeastern Asian species for which associations are now unknown.

In attempting to follow a biogeographical approach to taxonomy, we made a preliminary assessment of *Annulohypoxylon* species that might be found in Thailand. Several species and varieties are known only from southeastern Asia (Ju & Rogers 1996, Ju et al. 2004, Fournier et al. 2010), including *Annulohypoxylon bahnphadengense* (Thailand), *A. bovei* var. *microsporum* (J.H. Mill.) Y.M. Ju et al. (China, Japan, Philippines, Taiwan), *A. discophorum* (Penz. & Sacc.) Y.M. Ju et al. (Indonesia), *A. elevatidiscum* (Y.M. Ju et al.) Y.M. Ju et al. (Taiwan), *A. ilanense* (Y.M. Ju & J.D. Rogers) Y.M. Ju et al. (Taiwan), *A. maeteangense* J. Fourn. & M. Stadler (Thailand), *A. microcarpum* (Penz. & Sacc.) Y.M. Ju et al. (Indonesia), *A. moriforme* var. *microdiscum* (Y.M. Ju & J.D. Rogers) Y.M. Ju et al. (Taiwan), and *A. urceolatum* (Philippines, Sri Lanka, and Taiwan). These were the first taxa checked when identifying our specimens collected in Thailand. Although we recorded only two species (*A. bahnphadengense* and *A. urceolatum*) again in 2011, we expect others will be represented by additional collections in the future.

There are a few other species reported from both southeastern Asia and the tropics of the western hemisphere, but their types and many other specimens are mostly from the eastern hemisphere. For example, *Annulohypoxylon nitens* (Ces.) Y.M. Ju et al., described originally from Malaysia, has been found also in China, Philippines, Sri Lanka, and Taiwan. Its occurrence in Thailand has been reported by Suwannasai et al. (2002, 2005), Thienhirun et al. (2003), Thienhirun & Whalley (2004), Phosri et al. (2008), and Okane et al. (2008). Records of *A. nitens* from Mexico and Puerto Rico (Ju & Rogers 1996), Argentina (Hladki & Romero 2009), and Brazil (Pereira et al. 2010b) may represent a different taxonomic entity (cf. Vasilyeva et al. 2012, Vasilyeva & Stephenson 2014). In contrast to the southeastern Asian concentration of *A. nitens,* the distribution of *A. stygium* (Lév.) Y.M. Ju et al. is centered primarily in the Caribbean Basin. Specimens reported from Indonesia and Malaysia as *Hypoxylon stygium* (e.g., Whalley & Whalley 2007) might be assigned to other species (such as *Hypoxylon bogoriense* and *H. stigmoideum* Ces.) described previously from these countries, and the unification of the three entities (*H. bogoriense*, *H. stigmoideum*, *H. stygium*) into a single species (Ju & Rogers 1996) might need further consideration. Collections from Thailand identified as *H. stygium* (Whalley et al. 1995, Suwannasai et al. 2002, 2005, Thienhirun et al. 2003, Tang et al. 2007, Phosri et al. 2008) might also represent different species.

Materials & methods

The specimens considered herein were collected in two provinces in northern Thailand: Chiang Mai (Mae Taeng District near the villages of Pha Deng and Mae Sae; and the Doi Suthep temple in the vicinity of the city of Chiang Mai) and Chiang

Rai (Doi Pui Mountain in the Muang District). Microscopic analyses were carried out using standard techniques. Material was mounted in 10% KOH for examination of stromatal pigments and dehiscence of the perispore, and Melzer's iodine reagent was used for examination of the ascal apical ring. Color designations follow Rayner (1970). Photographs of stromata and associated structures were taken using a Nikon D40x digital camera. Measurements were obtained from about 15 ascospores and 5 glomerate stromata to represent the range of variation. The material from Thailand is deposited in the herbarium of Mae Fah Luang University, Chiang Rai, Thailand (MFLU).

Taxonomy

Annulohypoxylon bahnphadengense J. Fourn. & M. Stadler, Fungal Diversity 40: 30. 2010 Figs 1, 15a

Specimen examined: **THAILAND**, **Chiang Mai Province**, Mae Taeng District, Pha Deng village, Mushroom Research Centre, on wood, 19 June 2011, L. Vasilyeva (MFLU11-1165).

Note: *Annhulohypoxylon bahnphadengense,* characterized by effused-applanate, dull black to shiny black stromata, yielding grayish sepia (106) pigments in 10% KOH, ostiolar discs 0.25–0.3 mm diam., ascospores 6.5–8 × 3–3.5 µm, with a faint straight germ slit spore-length, perispore dehiscent in 10% KOH, and described only recently by Fournier et al. (2010), was collected again in same general locality.

Annulohypoxylon bogoriense (Höhn.) Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **comb. nov.** Figs 2, 15b

MycoBank MB 801406

≡ *Hypoxylon bogoriense* Höhn., Sitz. K. Akad. Wiss. Math.-Nat. Kl., Abt. 1, 118: 341. 1909.

Stromata effused, rather plane, with mostly inconspicuous (sometimes conspicuous) perithecial mounds at the margins, surface brown or dark-reddish-brown to the naked eye but pinkish between the black ostiolar discs in direct light and under low magnification, shiny black around the individual perithecia, with citrine (13) to olivaceous buff (89) KOH-extractable pigments. Perithecia spherical, 0.3–0.4 mm diam., ostioles papillate, encircled with a slightly concave or flat ostiolar discs 0.2–0.25 mm diam. Asci not observed. Ascospores light brown, ellipsoid-inequilateral, 5–7 × 2.4–3 µm, with a straight germ slit shorter than the spore length; perispore dehiscent in 10 % KOH.

Specimen examined: **THAILAND**, **Chiang Mai Province**, Mae Taeng District, Pha Deng village, Mushroom Research Centre, on wood, 24 June 2011, L. Vasilyeva (MFLU11-1166).

Notes: *Hypoxylon bogoriense* was listed as a synonym of *Hypoxylon stygium* by Ju & Rogers (1996). Our illustration (Fig. 2) of the specimen from Thailand

shows the pinkish stromatal surface between the black ostiolar discs, which is similar to *A. atroroseum* (J.D. Rogers) Y.M. Ju et al. *Annulohypoxylon stygium* and *A. atroroseum* share many similar features, but mature stromata are usually shiny black in *A. stygium*, whereas those of *A. atroroseum* are rose-colored with a black ostiolar region (Ju & Rogers 1996). However, the mature stromata in our specimen from Thailand are not rose-colored; this tint is apparent only in direct light and under low magnification when photographed, and the actual color is dark brown or in accordance with Höhnel's (1909) description of *Hypoxylon bogoriense* as being violet-brown and darkening with the age. Moreover, Rogers (1981) described *H. atroroseum* as having conspicuously sunken ostiolar discs, whereas those in our specimen are slightly concave and almost flat, thus slightly elevated above the surface. As Höhnel indicated, the flat-convex tops of the perithecia, always at the margins but rarely in the middle parts of the stromata, stick out ("Scheitel der randständigen Perithecien stets, seltener auch der mittelständigen flachkonvex vorragend;" Höhnel 1909, p. 341), and this condition corresponds to our specimen. Although *H. atroroseum* has been reported from Thailand (Suwannasai et al. 2005, Phosri et al. 2008), it was described originally from the west of central Africa (Gabon), and all specimens from Thailand might represent *H. bogoriense*, originally described from Indonesia.

Annulohypoxylon chiangmaiense Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 3, 15c

MycoBank MB 801393

Differs from *Annulohypoxylon bahnphadengense* by its larger ascospores and its citrine to olivaceous buff KOH-extractable pigments

Type: Thailand, Chiang Mai Province, Mae Taeng District, Pha Deng village, Mushroom Research Centre, on wood, 22 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1167).

Etymology: refers to the province where the fungus was collected.

Stromata effused-pulvinate, with perithecial mounds 1/2 to 1/4 exposed, surface at first brownish-olivaceous, then dark brown, with black granules immediately beneath surface and citrine (13) to olivaceous buff (89) KOH-extractable pigments. Perithecia spherical, 0.4–0.5 mm diam., ostioles papillate, encircled with flat ostiolar discs 0.3–0.35 mm diam. Asci in the spore-bearing portions 70–80 × 4.5–5 µm, the stipes ≤60 µm, with a tiny apical ring bluing in Melzer's iodine reagent. Ascospores brown, ellipsoid-inequilateral, 8.5–9.5 × 4-5 µm, with a straight germ slit slightly shorter than the length of the spore; perispore dehiscent in 10 % KOH.

Notes: *Annulohypoxylon chiangmaiense* is superficially quite similar to *A. bahnphadengense,* also collected from the same site. However, the pigments

Figs. 1–3. Stromata: 1. *Annulohypoxylon bahnphadengense*. 2. *A. bogoriense*. 3. *A. chiangmaiense*. Scale bars: 1, 2, 3a = 0.4 mm; 3b = 1.7 mm.

of *A. bahnphadengense* are grayish sepia and its light-brown ascospores (Fig. 15a) are 6.5–8.4 µm long (7.5 µm in average). It is also noteworthy that young portions of the stromata in *A. chiangmaiense* are brownish-olivaceous.

Annulohypoxylon derelictum Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Fig. 4

MycoBank MB 801394

Differs from other *Annulohypoxylon* species in lacking KOH-extractable pigments.

Type: Thailand, Chiang Mai Province, Muang District, T. Thasai, on dead branch of *Dipterocarpus* (?), in a dipterocarp forest, 30 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1168).

Etymology: from the Latin *derelictus,* meaning 'abandoned' or 'neglected'.

Stromata effused-pulvinate, with perithecial mounds 1/4 exposed or inconspicuous, surface dull black, blackish granules immediately beneath surface, without apparent KOH-extractable pigments. Perithecia spherical, 0.3–0.5 mm diam., ostioles papillate and encircled with a flat or slightly concave disc 0.2–0.3 mm diam. Asci not observed. Ascospores brown to light brown, ellipsoid-inequilateral, 8–10.5 × 4.5–5.2 µm, with a straight germ slit almost the length of the spore; perispore dehiscent in 10% KOH.

Note: The most prominent feature of *A. derelictum* is the lack of KOH-extractable pigments, a condition not previously recorded for *Annulohypoxylon*.

Annulohypoxylon dipterocarpi Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 5, 15g

MycoBank MB801395

Differs from *Annulohypoxylon purpureonitens* by its smaller ostiolar discs and larger ascospores.

Type: Thailand, Chiang Mai Province, Muang District, T. Thasai, on dead branch of *Dipterocarpus* (?), in a dipterocarp forest, 30 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1169).

Etymology: refers to the genus of the probable host plant, with the specimen collected in an almost pure dipterocarp forest.

Stromata effused-pulvinate, with perithecial mounds 1/2 to 1/4 exposed or inconspicuous, surface black to the naked eye but brownish under direct light, blackish granules immediately beneath the surface, KOH-extractable pigments vinaceous purple (101). Perithecia spherical, 0.3–0.5 mm diam., ostioles papillate and encircled with a small concave disc about 0.1–0.2 mm diam. Asci 70–80 × 5–6 µm long in the spore-bearing portions, the stipes 30–35 µm long, with an apical part not bluing in Melzer's iodine reagent. Ascospores brown to

light brown, ellipsoid-inequilateral, (8–)9–11(–12) × 4.5–5 µm, with a straight germ slit the length of the spore; perispore dehiscent in 10% KOH.

Notes: *Annulohypoxylon dipterocarpi* has vinaceous purple KOH-extractable pigments and is characterized by effused pulvinate stromata similar to *A. purpureonitens* (Y.M. Ju & J.D. Rogers) Y.M. Ju et al., known only from Brazil and Mexico (Ju & Rogers 1996); *A. purpureonitens* differs in having larger ostiolar discs (0.2–0.5 mm diam.) and smaller ascospores (6.5–10 µm). The lack of a positive Melzer's iodine reaction in the asci is also diagnostic for *A. dipterocarpi*. When the perithecia are crashed in a mount, a mass of tiny ellipsoid spores 1.5–3 µm long appears together with asci and ascospores, suggesting a conidial state within the stromata but probably instead a hyperparasitic anamorphic fungus.

Annulohypoxylon maesaeense Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 6a, 15h

MycoBank MB801396

Differs from *Annulohypoxylon moriforme* by its larger ascospores.

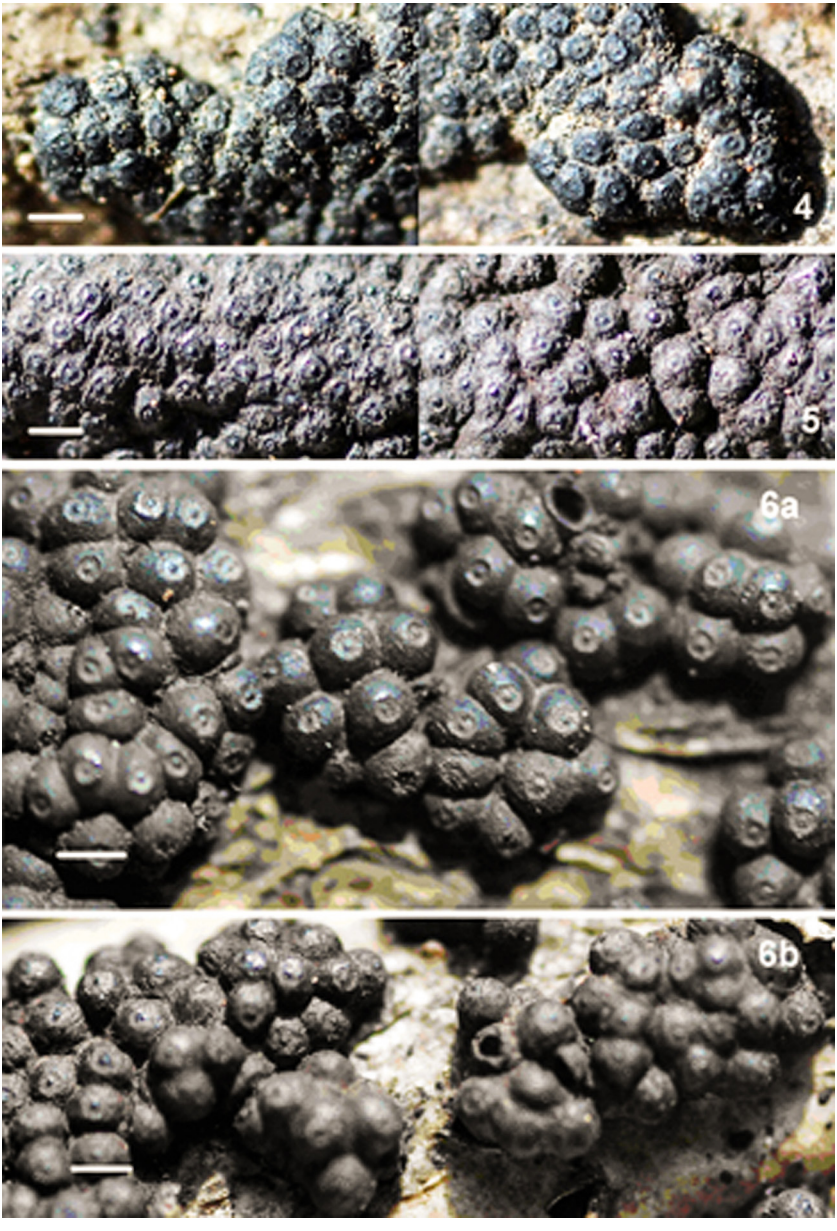
Type: Thailand, Chiang Mai Province, Mae Taeng district, near Mae Sae village, on the bark of an unidentified tree, 23 June 2011, S. Stephenson & T. Ko Ko (**Holotype,** MFLU11-1170).

Etymology: from the Mae Sae village where the specimen was collected.

Stromata glomerate, 3–5 mm diam., often confluent, with perithecial mounds 1/2 to 1/4 exposed, surface dark brown, blackish granules immediately beneath surface, with pale olivaceous but mostly slightly hazel (88) tinted KOH-extractable pigments. Perithecia spherical, ≤1 mm diam., ostioles papillate and encircled with a concave disc ≤0.3–0.35 mm diam. Asci not observed. Ascospores brown, ellipsoid-inequilateral, (8–)10–12(–12.5) × 4.5–5.5 µm, with a straight or oblique germ slit extending the length of the spore or slightly shorter; perispore dehiscent in 10% KOH.

Notes: Based on the key to taxa of *Hypoxylon* sect. *Annulata* (Ju & Rogers 1996), of the species characterized by having ascospores with a dehiscent perispore, ostiolar discs 0.2–0.5 mm diam, and dull brownish mature stromata), only two resemble *A. maesaeense*—*A. moriforme* (Henn.) Y.M. Ju et al. and *A. truncatum* (Schwein.) Y.M. Ju et al., both also reported from Thailand (Whalley et al. 1995, Suwannasai et al. 2002, Thienhirun et al. 2003, Phosri et al. 2008, Okane et al. 2008).

Annulohypoxylon moriforme, said to occur in the tropics and subtropics of both hemispheres (Ju & Rogers 1996), is distinguished from *A. truncatum* and *A. maesaeense* by its smaller ascospores (6–9 × 2.5–4 µm). One variety, *A. moriforme* var. *microdiscum* from Taiwan, has larger ascospores comparable



Figs. 4–6. Stromata: 4. *Annulohypoxylon derelictum*. 5. *A. dipterocarpi*. 6a. *A. maesaeense*. 6b. *A. truncatum* on *Quercus* (from Ouachita Mountains, Arkansas, VLA P-2156). Scale bars: 4, 5 = 0.4 mm; 6a = 0.8 mm; 6b = 1 mm.

in size to those of *A. maesaeense,* but differs by having ostiolar discs smaller than 0.2 mm diam.

Annulohypoxylon truncatum (Fig. 6b) differs from *A. maesaeense* in having greenish olivaceous (90) to dull green (70) KOH-extractable pigments. Moreover, *A. truncatum* has been reported to inhabit *Quercus* in temperate regions, but species records actually have been indicated only from Mexico and the southeastern United States (North Carolina, Georgia, Louisiana, Massachusetts, Pennsylvania; Ju & Rogers 1996) as well as from Tennessee (Vasilyeva et al. 2007) and Arkansas and Texas (our unpublished data). *Annulohypoxylon truncatum* has also been recorded (as *Hypoxylon truncatum*) from Japan (Abe 1990, Abe & Doi 2000) and Korea (Velmurugan et al. 2007), not unexpected given that an appreciable number of pyrenomycetous fungi occur in both eastern North America and temperate regions of eastern Asia (Vasilyeva & Stephenson 2010). However, the eastern Asian material of *A. truncatum* needs to be reconsidered, in light of the redetermination of a specimen identified as "*A. truncatum*" from the Russian Far East (Vasilyeva 1998) to *A. orientale* Lar.N. Vassiljeva & S.L. Stephenson (Vasilyeva et al. 2013).

Annulohypoxylon microbovei Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 7, 15d

MycoBank MB801397

Differs from other species of the *Annulohypoxylon bovei* complex by its very small ostiolar discs.

Type: Thailand, Chiang Mai Province, vicinity of Chiang Mai city, near Doi Suthep temple, Huai Kok Ma, on dead branches of unidentified tree, 21 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1171).

Etymology: refers to the similarity of this fungus to the *Annulohypoxylon bovei* complex, albeit having smaller ostiolar discs.

Stromata glomerate or effused-pulvinate, mostly confluent, with perithecial mounds 1/4 to 3/4 exposed, surface dark brown, blackish granules immediately beneath surface, with citrine (13) to hazel (88) tinted KOH-extractable pigments. Perithecia spherical, 0.5–0.7 mm diam., ostioles papillate and encircled with a slightly concave or flat disc 0.2–0.3 mm diam. Asci not observed. Ascospores brown, ellipsoid-inequilateral, 8–11 × 4.5–5.5 µm, with a straight germ slit spore length; perispore dehiscent in 10% KOH.

Notes: The stromata and ostiolar discs in *A. microbovei* are similar to those in *A. bovei* (Speg.) Y.M. Ju et al., especially as illustrated by Miller (1961, Figs 158, 159). *Annulohypoxylon bovei* var. *microsporum,* widely distributed in southeastern Asia, is also known from China, Japan, Philippines, and Taiwan

(Ju & Rogers 1996) and shares a number of features (including ascospore size) with *A. microbovei* but differs in its larger (0.3–0.7 mm diam) ostiolar discs.

Annulohypoxylon morisuspectum Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 8, 15e

MycoBank MB801398

Differs from *Annulohypoxylon moriforme* by its flat ostiolar discs and its brownish stromatal surface.

Type: Thailand, Chiang Mai Province, vicinity of Chiang Mai city, near Doi Suthep temple, Huai Kok Ma, on dead branches of unidentified tree, 21 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1172).

Etymology: as compared with *A. moriforme*, with which it shares a number of similar features.

Stromata glomerate, 1.5–2.5 mm diam., often confluent, with perithecial mounds 1/2 to 1/4 exposed, surface dark brown, blackish granules immediately beneath surface, with greenish to citrine (13) KOH-extractable pigments. Perithecia spherical, 0.4–0.5 mm diam., ostioles finely papillate and encircled with a flat disc 0.2–0.3 mm diam. Asci 60–70 × 4–5 µm long in the spore-bearing portions, the stipes 35–50 µm long, with an apical ring bluing in Melzer's iodine reagent, discoid, 1.5–2 µm broad. Ascospores brown to light brown, ellipsoid-inequilateral, 7.5–10 × 3–4.5 µm, with a straight germ slit slightly shorter than the length of the spore; perispore of at least some spores dehiscent in 10% KOH, but rarely.

Notes: *Annulohypoxylon morisuspectum* resembles *A. moriforme* and *A. truncatum,* which are distinguished by their stromata with concave ostiolar discs of the *truncatum*-type; *A. moriforme* is further distinguished by the olivaceous shades of its stromatal surface (Ju & Rogers 1996).

Annulohypoxylon neglectum Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 9, 15i

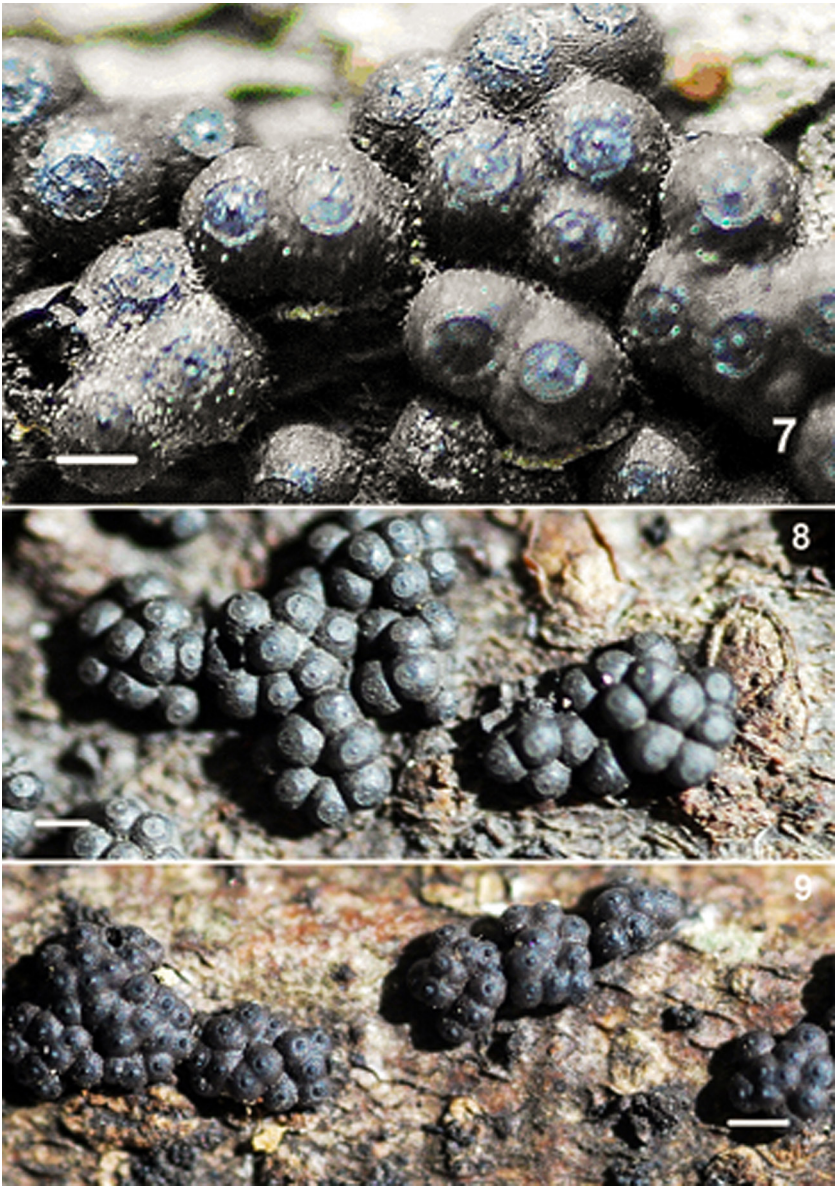
MycoBank MB801400

Differs from *Annulohypoxylon purpureopigmentum* by its smaller ascospores.

Type: Thailand, Chiang Mai Province, vicinity of Chiang Mai city, near Doi Suthep temple, Huai Kok Ma, on dead branches of an unidentified tree, 21 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1173).

Etymology: refers to the small and inconspicuous, easily overlooked stromata.

Stromata small, glomerate, 1.5–2 mm diam., often confluent, with perithecial mounds 1/3 to 1/4 exposed, surface dark brown, almost black to the naked eye, with a purplish tint under the dissecting microscope, blackish granules immediately beneath surface, with dilute bay (6) to purplish KOH-extractable



Figs. 7–9. Stromata: 7. *Annulohypoxylon microbovei*. 8. *A. morisuspectum*. 9. *A. neglectum*. Scale bars: 7 = 0.5 mm; 8 = 0.6 mm; 9 = 0.7 mm.

pigments. Perithecia spherical, 0.2–0.3 mm diam., ostioles rather coarsely papillate and encircled with a concave disc 0.15–0.2 mm diam. Asci 40–50 × 3.5–4 µm long in the spore-bearing portions, the stipes 15–20 µm long, with an apical ring bluing in Melzer's iodine reagent, discoid, about 0.5–0.7 µm broad. Ascospores light brown, ellipsoid-inequilateral, 4–6.3 × 2.5–3 µm, with a straight germ slit, perispore dehiscent in 10% KOH

Notes: Despite its inconspicuous habit, *A. neglectum* possesses features uncommonly encountered in *Annulohypoxylon*, and their combination in the same taxon is noteworthy. Very small ascospores were reported for *A. atroroseum*, *A. ilanense* and *A. stygium*, but these species differ from *A. neglectum* by their widely effused stromata; in addition, *A. ilanense* differs by its brick colored KOH-extractable pigments (Ju & Rogers 1999), and *A. atroroseum* and *A. stygium* by their greenish olivaceous (90) to dull green (70) pigments (Ju & Rogers 1996).

Purplish KOH-extractable pigments are present in *A. purpureonitens* and *A. urceolatum*; the pigments in *A. neglectum* are similar but lack a vinaceous tinge (101 or 116). *Annulohypoxylon minutellum* (Syd. & P. Syd.) Y.M. Ju et al. [= *Hypoxylon cohaerens* var. *microsporum* J.D. Rogers & Cand.] has vinaceous to rusty KOH-extractable pigments (Hsieh et al. 2005), but this species does not have annulate ostioles. *Annulohypoxylon purpureopigmentum* Jad. Pereira et al. (Pereira et al. 2010a, Fig. 16) is characterized by purple vinaceous KOH-extractable pigments, but the ascospores (6.5–8(–10) µm long) are larger than those of *A. neglectum*. The appearance of glomerate stromata with large coarse papillae that almost fill up the concave discs is typical for *A. neglectum* and for *A. purpureopigmentum*, which seems the most similar western hemisphere species to *A. neglectum*.

Annulohypoxylon paratruncatum Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 10a, 15f

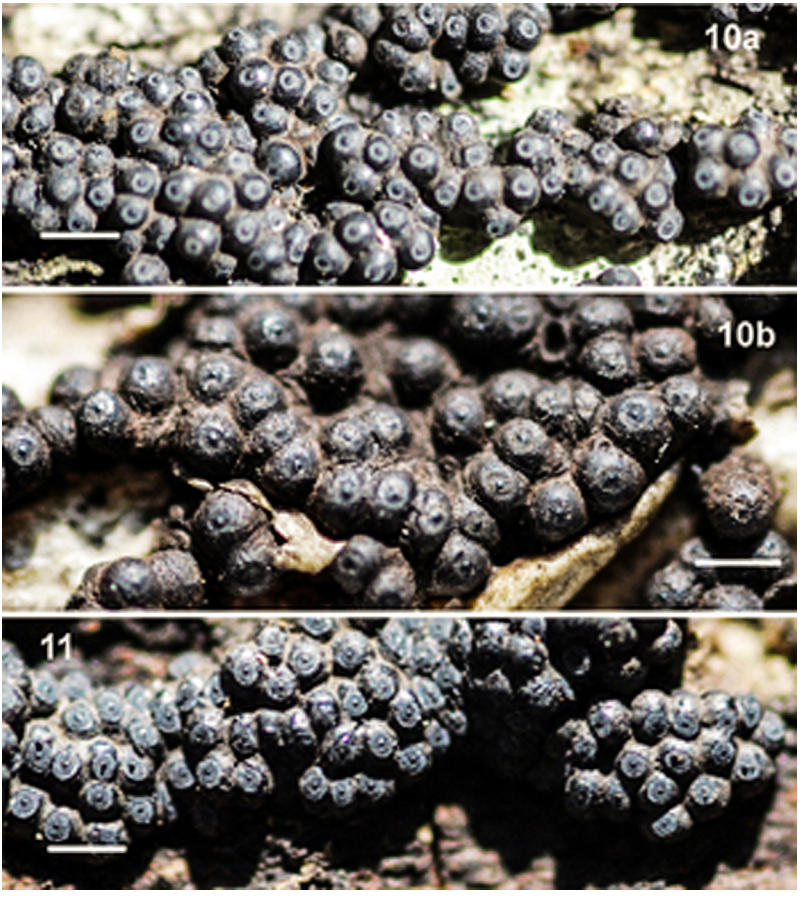
MycoBank MB801401

Differs from *Annulohypoxylon truncatum* by its smaller ostiolar discs and its citrine to olivaceous-buff KOH-extractable pigments.

Type: Thailand, Chiang Mai Province, Mae Taeng District, Pha Deng village, Mushroom Research Centre, on the bark, 19 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1174).

Etymology: refers to the close similarity of the new fungus to *A. truncatum*.

Stromata glomerate to effused-pulvinate, with perithecial mounds 1/2 to 1/4 exposed, surface dull black to the naked eye, dark brown under the dissecting microscope, blackish granules immediately beneath surface, with citrine (13) to olivaceous-buff (89) KOH-extractable pigments. Perithecia spherical, 0.3–0.4 mm diam., ostioles papillate and encircled with a concave disc about 0.2



Figs. 10–11. Stromata: 10a. *Annulohypoxylon paratruncatum*.
10b. *A. truncatum* (from Ouachita Mountains, Arkansas, VLA P-2156). 11. *A. planodiscum*.
Scale bars: 10a = 1 mm; 10b = 0.9 mm; 11 = 1.3 mm.

(–0.25) mm diam. Asci 60–80 × 4.5–5 µm long in the spore-bearing portions, the stipes 15–20 µm long, with an apical ring bluing in Melzer's iodine reagent, discoid, about 0.5 µm broad. Ascospores brown to light brown, ellipsoid-inequilateral, 8–10.5 × 4–4.6 µm, with a straight germ slit shorter than length of the spore; perispore dehiscent in 10% KOH.

Notes: Images of stromata show that *A. paratruncatum* (Fig. 10a) and *A. truncatum* (Fig. 10b) are superficially very similar; however, *A. truncatum,* which appears to have much larger perithecia and ostiolar discs, also differs by its greenish olivaceous (90) to dull green (70) KOH-extractable pigments.

Annulohypoxylon planodiscum Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 11, 15j

MycoBank MB801402

Differs from *Annulohypoxylon elevatidiscum* by its glomerate stromata and flat ostiolar discs.

Type: Thailand, Chiang Mai Province, Muang District, Doi Pui Mountain, on the trunk of an unidentified tree, 30 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1175).

Etymology: refers to the mostly flat ostiolar discs.

Stromata glomerate (seemingly effused-pulvinate when confluent), with perithecial mounds 1/2 to 1/4 exposed, surface dull black (sometimes overlaid with a white substance, blackish granules immediately beneath the surface), with greenish-olivaceous (90) KOH-extractable pigments. Perithecia spherical, 0.3–0.4 mm diam., ostioles papillate and encircled with a flat disc 0.2–0.3 mm diam. Asci 60–80 × 4.5–5 µm in the spore-bearing portions, the stipes 15–20 µm long, with an apical ring bluing in Melzer's iodine reagent, discoid, about 0.5 µm broad. Ascospores brown to light brown, ellipsoid-inequilateral, 9–11.5 × 4–5 µm, with a straight germ slit spore extending the length of the convex side of the spore; perispore dehiscent in 10% KOH.

Notes: The combination of several key characters in the type of *A. planodiscum*—greenish olivaceous KOH-extractable pigments, a 0.2–0.3 mm diam ostiolar disc, a straight germ slit on the convex side of the ascospores, and a perispore dehiscent in 10% KOH—are also found in *A. elevatidiscum* (Ju et al. 2004), which differs by its slightly larger ascospores and regularly effused-pulvinate stromata. Although some *A. planodiscum* discs appear to be slightly convex, the majority are flat, with its stromata initially glomerate and only later confluent, like those of *A. truncatum*.

Annulohypoxylon pseudonitens Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 12, 15l

MycoBank MB801403

Differs from *Annulohypoxylon nitens* by its smaller ascospores and its smaller ostiolar discs.

Type: Thailand, Chiang Mai Province, vicinity of Chiang Mai city, near Doi Suthep temple, Huai Kok Ma, on dead branches of an unidentified tree, 21 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1176).

Etymology: refers to the similarity of this species with *Annulohypoxylon nitens* in a number of features.

Stromata effused-pulvinate, with perithecial mounds 1/2 to 1/4 exposed, surface dull to shiny black in some parts, blackish granules immediately beneath the surface, with citrine (13) KOH-extractable pigments. Perithecia

spherical, 0.3–0.5 mm diam., ostioles papillate and encircled with a concave disc about 0.2 mm diam. Asci 60–65 × 4–4.5 µm in the spore-bearing part, stalks 20–25 µm long, with an apical ring bluing in Melzer's iodine reagent, discoid, about 0.5 µm broad. Ascospores brown to light brown, ellipsoid-inequilateral, 5–7.5 × 2.5–3 µm, with a straight or slightly oblique germ slit shorter than the length of the spore; perispore dehiscent in 10% KOH.

Notes: *Annulohypoxylon pseudonitens* resembles *A. nitens* in having shiny black mature stromata, somewhat exposed perithecial mounds, smaller ascospores, and greenish tinged KOH-extractable pigments. However, the ascospore length in *A. pseudonitens* does not exceed 7.5 µm, overlapping with the lower range cited for *A. nitens* (6.5–10(–11) µm long; Ju & Rogers 1996). As *A. nitens* has been reported previously from Thailand (Suwannasai et al. 2002, 2005, Thienhirun et al. 2003, Okane et al. 2008, Phosri et al. 2008), we first assigned our specimen to *A. nitens*. However, the type specimen of *A. nitens* [≡ *Rosellinia nitens* Ces.], treated as a synonym of *Hypoxylon truncatum* (Schwein.) J. Mill. (Miller 1961), is cited as having 8–12 µm long ascospores (cf. Saccardo 1882, Miller 1961). In addition Hladki & Romero (2009) cite longer (8–9 µm) ascospores for a specimen of *A. nitens* from Argentina. The material of *A. nitens* from China and Philippines, identified previously as *Hypoxylon bovei* var. *microsporum*, also has 8–10 µm long ascospores (Miller 1961, Ju & Rogers 1996), exceeding the spore length of *A. pseudonitens*.

Annulohypoxylon bovei and its variety differ from *A. pseudonitens* by their mainly glomerate stromata.

Annulohypoxylon sordidum Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Figs 13, 15k

MycoBank MB801404

Differs from *Annulohypoxylon moriforme* by its effuse stromata and pale fawn KOH-extractable pigments.

Type: Thailand, Chiang Mai Province, Mae Taeng District, Pha Deng village, Mushroom Research Centre, on wood, 20 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1177).

Etymology: derived from the Latin *sordidus,* meaning 'dirty-looking'.

Stromata effused-pulvinate, with perithecial mounds 1/2 to 1/4 exposed, surface dull, dark brown, blackish granules immediately beneath surface, with dilute fawn (87) KOH-extractable pigments. Perithecia spherical, 0.3–0.4 mm diam., ostioles papillate and encircled with a tiny concave disc up to 0.1 mm diam. Asci 80–85 × 4.5–5 µm in the spore-bearing part, stalks 15–20 µm long, with an apical ring bluing in Melzer's reagent, discoid, about 0.5–0.7 µm broad. Ascospores brown to light brown, ellipsoid-inequilateral, 9–11(–12) ×

Figs. 12–14. Stromata: 12. *Annulohypoxylon pseudonitens*. 13. *A. sordidum*. 14. *A. urceolatum*. Scale bars: 12, 13 = 0.6 mm; 14 = 1.4 mm.

4–5.5 µm, with a straight germ slit slightly shorter than the length of the spore; perispore infrequently dehiscent in 10% KOH.

Notes: *Annulohypoxylon sordidum* has very small ostiolar discs similar to those of *A. moriforme* var. *microdiscum*, but both *A. moriforme* varieties are characterized by basically glomerate and blackish stromata with olivaceous shades, as well as greenish olivaceous (90) to dull green (70) KOH-extractable pigments.

The stroma of *A. sordidum* illustrated in Fig. 13 is somewhat similar to that of *A. pyriforme* (Y.M. Ju & J.D. Rogers) Y.M. Ju et al. (Ju & Rogers 1996, Fig. 14G) in having rather prominent perithecial mounds and small ostiolar discs. *Annulohypoxylon pyriforme* differs in its slightly smaller (8–10 × 3.5–4 µm) pyriform ascospores, a perispore that is always indehiscent in 10% KOH, and dull green to dark green KOH-extractable pigments. *Annulohypoxylon sordidum* may represent a western hemisphere counterpart of *A. pyriforme,* known only from Venezuela (Cerro de la Neblina).

Annulohypoxylon urceolatum (Rehm) Y.M. Ju, J.D. Rogers & H.M. Hsieh, Mycologia 97: 861. 2005. Fig. 14

Specimen examined: Thailand, Chiang Mai Province, Muang District, Doi Pui Mountain, on the branch of an unidentified tree, 30 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1178).

Notes: *Annulohypoxylon urceolatum* is described in Ju & Rogers (1996, as *Hypoxylon urceolatum*). As indicated earlier, this species has been found only in southeastern Asia, but our record is the first for Thailand. We observed all the main features of this species such as the vinaceous purple KOH-extractable pigments, ascospores that are 9–14 × 3.5–4.5 µm, and a perispore that in our specimen is indehiscent in 10% KOH.

Key to the species of *Annulohypoxylon* considered in this paper

(New species indicated in bold font)

1. Stromata without apparent KOH-extractable pigments, effused-pulvinate; ascospores 8–10.5 µm long ..... ***A. derelictum***
1. Stromata with KOH-extractable pigments 2
2. KOH-extractable pigments grayish-sepia, stromata widely effused, ascospores 6.5–8.4 µm long ..... *A. bahnphadengense*
2. KOH-extractable pigments of other colors 3
3. KOH-extractable pigments purplish tinged 4
3. KOH-extractable pigments of other colors 8
4. Stromata glomerate 5
4. Stromata widely effused 6
5. Ascospores 4–6.3 µm long ..... ***A. neglectum***
5. Ascospores 6.5–8 µm long ..... *A. purpureopigmentum*
6. Ascospores 8–12 µm long 7
6. Ascospores up to 14(–17) µm long ..... *A. urceolatum*
7. Ostiolar discs 0.1–0.2 mm diam ..... ***A. dipterocarpi***
7. Ostiolar discs larger, 0.2–0.5 mm diam ..... *A. purpureonitens*

8. KOH-extractable pigments greenish-olivaceous, dull green, citrine, olivaceous buff, or hazel 9
8. KOH-extractable pigments brick colored ..... *A. ilanense*

9. Stromata glomerate, often confluent and then becoming effused-pulvinate 10
9. Stromata flat and widely effused 18

10. Ostiolar discs of the *bovei* type 11
10. Ostiolar discs of the *truncatum* type 13

11. Ostiolar discs 0.2–0.3 mm diam 12
11. Ostiolar discs 0.3–0.7 mm diam ..... *A. bovei* var. *microsporum*

12. Ascospores narrower (3–4.5 µm), perispore almost indehiscent in 10% KOH ..... ***A. morisuspectum***
12. Ascospores wider (4.5–5.5 µm), perispore dehiscent in 10% KOH ... ***A. microbovei***

13. Ascospores 6–7(–9) µm long ..... *A. moriforme*
13. Ascospores 8–12 µm long 14

14. Ostiolar discs do not exceed 0.2 mm diam 15
14. Ostiolar discs 0.2–0.4 mm diam 16

15. KOH-extractable pigments citrine to olivaceous-buff, ascospores 8–10 µm long ..... ***A. paratruncatum***
15. KOH-extractable pigments greenish olivaceous to dull green, ascospores 10–12 µm long ..... *A. moriforme* var. *microdiscum*

16. KOH-extractable pigments close to hazel tint ..... ***A. maesaeense***
16. KOH-extractable pigments greenish-olivaceous to dull green 17

17. Ostiolar discs concave ..... *A. truncatum*
17. Ostiolar discs flat ..... ***A. planodiscum***

18. Ostiolar discs of *bovei*-type ..... *A. nitens*
18. Ostiolar discs of *truncatum* type 19

19. Ostiolar discs up to 0.1 mm diam ..... ***A. sordidum***
19. Ostiolar discs larger 20

20. Ostiolar disc 0.2 mm diam ..... *A. pyriforme*
20. Ostiolar disc 0.3–0.4 mm diam 21

21. Ascospores 5–7 µm long 22
21. Ascospores 8.5–9.5 µm long ..... ***A. chiangmaiense***

22. Stromatal surface pinkish between black ostioles 23
22. Stromatal surface uniformly black 24

23. KOH-extractable pigments citrine to olivaceous-buff, ostiolar discs slightly concave or almost flat ..... *A. bogoriense*
23. KOH-extractable pigments greenish olivaceous to dull green, ostiolar discs conspicuously sunken ..... *A. atroroseum*

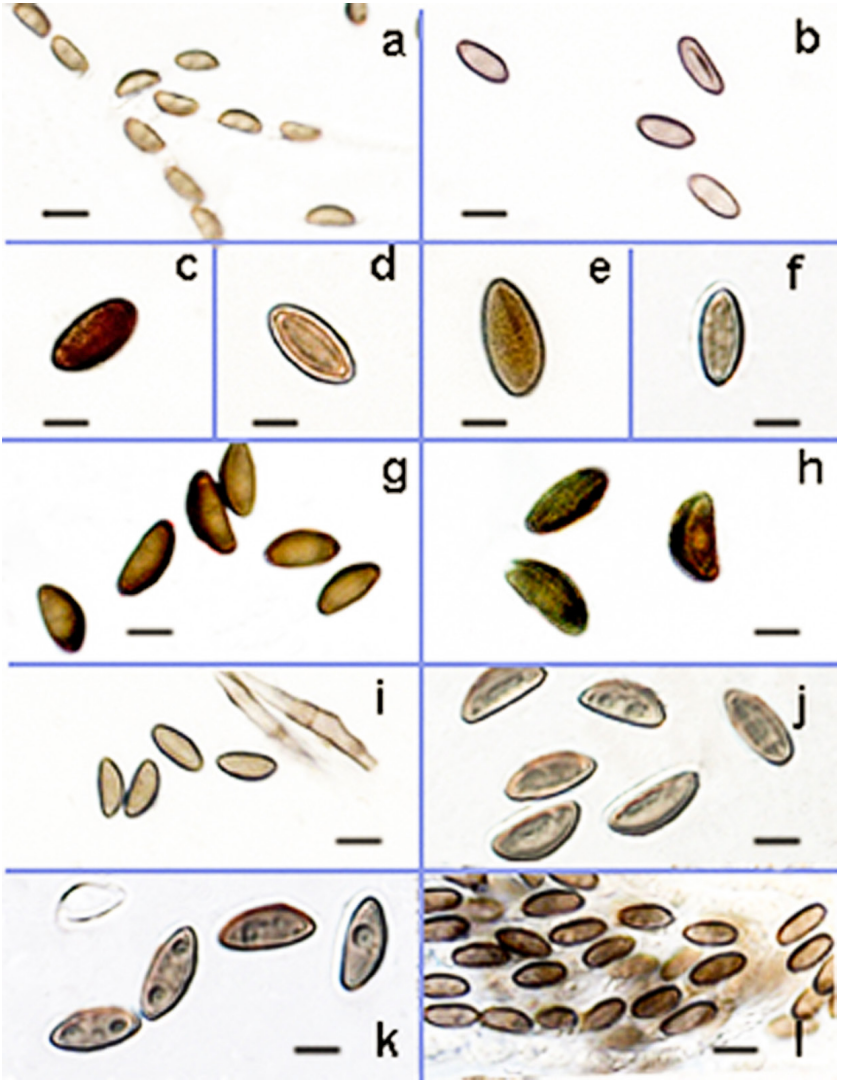


Fig. 15. Ascospores: a. *Annulohypoxylon bahnphadengense*. b. *A. bogoriense*. c. *A. chiangmaiense*. d. *A. microbovei*. e. *A. morisuspectum*. f. *A. paratruncatum*. g. *A. dipterocarpi*. h. *A. maesaeense*. i. *A. neglectum*. j. *A. planodiscum*. k. *A. sordidum*. l. *A. pseudonitens*. Scale bars: a = 7.5 µm; b–d, f, i = 4 µm; e = 3 µm; g, h, j–l = 5 µm.

24. KOH-extractable pigments citrine ..... ***A. pseudonitens***
24. KOH-extractable pigments greenish olivaceous to dull green ..... *A. stygium*

Ustulina pseudozonata Lar.N. Vassiljeva, S.L. Stephenson & K.D. Hyde, **sp. nov.** Fig. 16

MycoBank MB801405

Differs from *Ustulina zonata* by its larger ascospores and light-brownish stromata; and from *U. deusta* by its wider ascospores, longer germ slit, and light-brownish stromata.

Type: Thailand, Chiang Mai Province, Mae Taeng district, near Mae Sae village, on the bark of an unidentified tree, 23 June 2011, L. Vasilyeva (**Holotype,** MFLU11-1179).

Etymology: refers to some similarity with *Ustulina zonata*.

Stromata effused-pulvinate with the appearance of a flat elongated cake, 2.5–5 × 1.5–2.5 cm, light-brownish, with wavy and greyish margins, surface undulate, irregularly cracked, and very finely papillate, ostioles almost umbilicate. Perithecia tubular, 1–1.2 mm long, 0.4–0.6 mm wide. Asci in the spore-bearing portions 180–200 × 12–14 µm, stipes up to 200 µm long, with an apical ring bluing in Melzer's iodine reagent, urn-shaped, 7–7.5 × 3–4 µm. Ascospores brown, unicellular, fusoid-inequilateral, smooth, (27.5–)30–35 (–37.5) × 8–10(–12) µm, with a straight germ slit extending almost the length of the spore.

Notes: The name *Ustulina* is currently treated as a synonym of *Kretzschmaria* (Martin 1970, Læssøe 1994, Rogers & Ju 1998), but within *Kretzschmaria* sensu lato two taxonomic complexes can be clearly distinguished, the kretzschmarioid complex and the ustulinoid complex (Rogers & Ju 1998). Both complexes were accepted within a single genus based primarily on similar cultural features (Rogers & Ju 1998), but many other groups of xylariaceous genera (e.g., *Annulohypoxylon*, *Daldinia*, and *Hypoxylon* in one instance and *Entoleuca*, *Nemania*, and *Rosellinia* in another) known to share cultural features are nevertheless accepted as independent taxonomic entities (Stadler 2011).

We believe that *Ustulina* deserves recognition as a separate genus; among the ustulinoid taxonomic complex, the most closely related species to *U. pseudozonata* are *U. deusta* (Hoffm.) Lind and *U. zonata* (Lév.) Sacc. Rogers & Ju (1998) distinguish these two species in their key provided based on *U. deusta* having ascospores 27–35(–38) × 7–9 µm, a germ slit much shorter than the spore length, and a northern temperate distribution vs. *U. zonata* having ascospores 21–34 × 8.5–12 µm, a germ slit that is either the length of the spore or nearly so, and a subtropical and tropical distribution. The specimen from northern Thailand has the range in ascospores length characteristic of *U. deusta* but a germ slit that fits *U. zonata*, and this combination is enough to characterize it as a separate species.

Ustulina zonata, described from Java, has been mentioned repeatedly as a pathogen that causes root decay of trees in southeastern Asia (Brooks 1915,

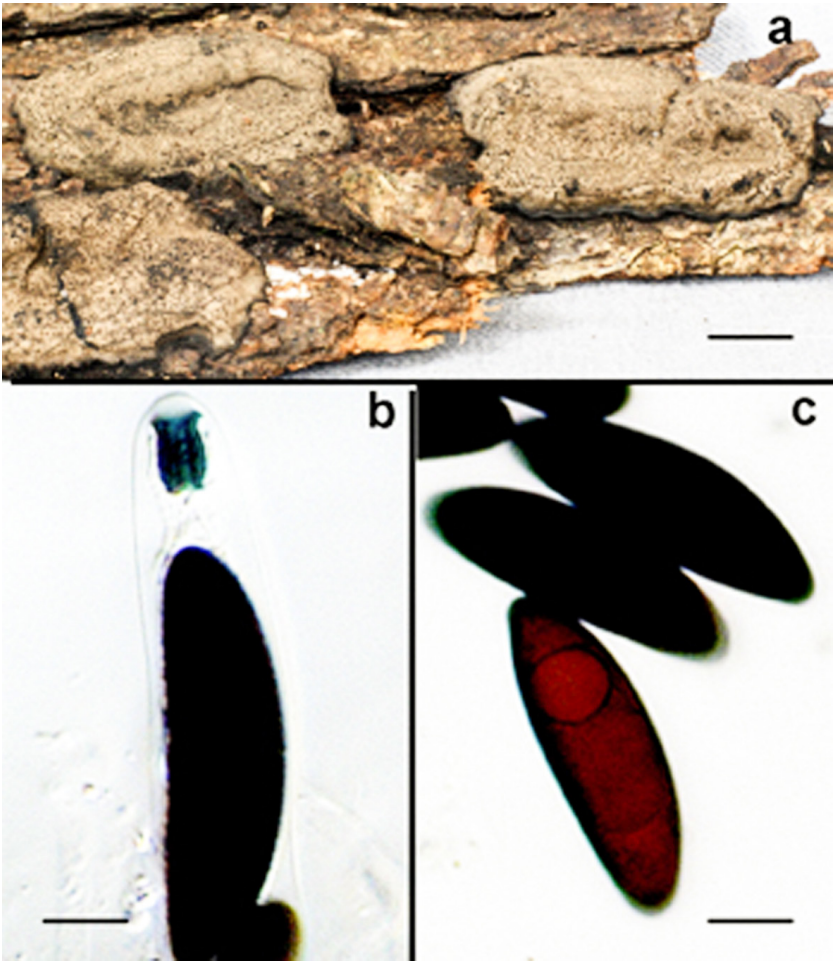


Fig. 16. *Ustulina pseudozonata*. a. Stromata (photo by Randy Darrah). b. Ascus top with an apical apparatus and an ascospore. c. Ascospores. Scale bars: a = 7 mm; b = 7 µm; c = 8 µm.

Petch 1928, Nandris et al. 1987, Muraleedharan & Baby 2007, Barthakur 2011). The only color illustration found on the Internet (http://www.ava.gov.sg) shows *U. zonata* as having carbonaceous fruit bodies hidden among grass and roots. The common name of the disease (charcoal stump root) seems to emphasize the black color of the stromata, although Petch (1928, p. 241) wrote that stromata usually referred to as representing *U. zonata* are "fairly frequently reddish on the surface, wholly or in part, but the majority of the specimens are, until

weathered, grey or purple-grey; when weathered, they are, of course, black." He was unable to locate Léveillé's type of *U. zonata* but found Léveillé's specimen of "*U. deusta*", which did not have zones on the fragment of a stroma, but had a reddish tinge. According to Petch, Léveillé distinguished *Ustulina zonata* from *U. vulgaris* (= *U. deusta*) by its reddish color and zoned surface. None of these features is mentioned by Rogers & Ju (1998), who indicate only that *U. zonata* has stromata, perithecia, ostioles, and asci similar to those found in *U. deusta*. In our specimen of *U. pseudozonata* from Thailand, the fully mature stromata are light brownish or sand-colored. This is the color reported for the maturing stromata in *Kretzschmaria milleri* J.D. Rogers & Y.M. Ju from the Caribbean Basin (French Guiana, Guyana, Mexico, Venezuela).

"*Ustulina zonata*" from southeastern Asia might represent a species complex waiting for separation into several separate taxa. Interestingly, almost all specimens listed under the description of *U. zonata* by Rogers & Ju (1998) are from the Caribbean Basin (Cuba, French Guiana, Guadeloupe, Mexico, Puerto Rico). Only one specimen from Taiwan was cited (Rogers & Ju 1998) for *U. zonata*, which differs from *U. pseudozonata* by its ascospores with pinched ends. Among the synonyms Rogers & Ju (1998) give for *Kretzschmaria zonata* is *Hypoxylon deustum* f. *madagascariensis* (Henn.) Hendr., which Dennis (1963) reported as having ascospores 20–28 × 7–10 µm and which Rogers & Ju noted very likely represented *Kretzschmaria zonata*. The specimens from Thailand and Madagascar are not conspecific, primarily due to the spore size differences that ostensibly demonstrate the heterogeneity of the *Ustulina zonata* 'complex.' Given the economic importance of *U. zonata* as a pathogen of many trees and shrubs, further taxonomic investigations are warranted.

Discussion

In this paper, we have increased the number of examples of closely related species known from the Caribbean and Indo-Malayan centers of biodiversity (cf. Vasilyeva et al. 2012). As noted in earlier treatments of species from temperate latitudes of northeastern Asia and eastern North America (Vasilyeva & Stephenson 2010, 2011), the morphological differences between species in the western and eastern hemispheres are rather insignificant and sometimes pertinent to only a single character (e.g., a difference in ascospore size, of anamorphs, or in stromatal pigments). This enigma currently has no biogeographic explanation but does demand an accumulation of relevant examples to solve.

Specimens of six different *Annulohypoxylon* taxa (as *Hypoxylon bovei* var. *microsporum*, *H. moriforme*, *H. nitens*, *H. purpureonitens*, *H. stygium*, *H. stygium* var. *annulatum*) reported from Thailand by Suwannasai et al. (2002)

were said to differ from taxa described previously by Ju & Rogers (1996) due to a high level of morphological variation in the species involved. However, the differences might as easily be explained by the completely different species composition of the fungal assemblage found in Thailand. In fact, morphological variation within *Hypoxylon* and *Annulohypoxylon* is not very high, as both the same characters (stromatal pigments and shapes, dehiscent or indehiscent perispore, etc.) and the same ranges of variation (e.g., size of ascospores) repeat themselves infinitely (cf. Vasilyeva & Stephenson 2010) while combining differently with one another other for a particular taxon. Diversity lies not in morphological variation per se, but rather in the combinations of features characterizing different species.

Acknowledgments

The research reported herein was funded in part by a grant (OISE-1042602) from the National Science Foundation to the University of Arkansas. The support provided by the Global Research Network for Fungal Biology and King Saud University is also gratefully acknowledged. Thanks are extended to Randy Darrah for providing the image used for Figure 16a. We are also thankful to Liliane Petrini (Breganzona, Switzerland) and Katherine Winsett (North Carolina State University, Raleigh, USA) for the thorough reading of our manuscript and their valuable comments.

Literature cited

Abe Y. 1990. Influence of moisture on rate of decay of beech wood by *Hypoxylon truncatum* or *Lentinus edodes*, and their oxygen requirements. Transactions of the Mycological Society of Japan 31: 45–53.

Abe Y, Doi Y. 2000. Wood-decaying ascomycetous fungi (*Ascomycota*, *Xylariales*) collected in the Fukiage Gardens of the Imperial Palace, Tokyo. Memoirs of the National Science Museum 34: 235–239.

Barthakur BK. 2011. Recent approach of Tocklai to plant protection in tea in North East India. Science et Culture 77: 381–384.

Brooks FT. 1915. A disease of plantation rubber caused by *Ustulina zonata*. New Phytologist 14: 152–164. http://dx.doi.org/10.1111/j.1469-8137.1915.tb07181.x

Dennis RWG. 1963. *Hypoxyloideae* of Congo. Bulletin du Jardin botanique de l'État à Bruxelles 33: 317–343.

Fournier J, Stadler M, Hyde KD, Duong ML. 2010. The new genus *Rostrohypoxylon* and two new *Annulohypoxylon* species from Northern Thailand. Fungal Diversity 40: 23–36. http://dx.doi.org/10.1007/s13225-010-0026-4

Hladki AI, Romero AI. 2009. Novedades para los géneros *Annulohypoxylon* e *Hypoxylon* (*Ascomycota*, *Xylariaceae*) en la República Argentina. Darwiniana 47: 278–288.

Höhnel F. 1909. Fragmente zur Mykologie (VI. Mitteilung, Nr. 182–288). Sitzungsberichten der Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftlichen Klasse, Abteilung I, 118: 275–452.

Hsieh HM, Ju YM, Rogers JD. 2005. Molecular phylogeny of *Hypoxylon* and closely related genera. Mycologia 97: 844–865. http://dx.doi.org/10.3852/mycologia.97.4.844

Ju YM, Rogers JD. 1996. A revision of the genus *Hypoxylon*. Mycologia Memoir 20. 365 p.

Ju YM, Rogers JD. 1999. The *Xylariaceae* of Taiwan (excluding *Anthostomella*). Mycotaxon 73: 343–440.

Ju YM, Rogers JD, Hsieh HM. 2004 *Hypoxylon* species and notes on some names associated with or related to *Hypoxylon*. Mycologia 96: 154–161. http://dx.doi.org/10.2307/3761997

Læssøe T. 1994. Index ascomycetum 1. *Xylariaceae*. Systema Ascomycetum 13: 43–112.

Martin PMD. 1970. Studies in the *Xylariaceae*: VIII. *Xylaria* and its allies. South African Journal of Botany 36: 73–137.

Miller JH. 1961. A monograph of the world species of *Hypoxylon*. University of Georgia Press, Athens.

Muraleedharan N, Baby UI. 2007 Tea diseases: ecology and control. 668–671, in: D Pimentel (ed.). Encyclopedia of Pest Management, vol. II. CRC Press. http://dx.doi.org/10.1201/9781420068467.ch173

Nandris D, Nicole M, Geiger JP. 1987. Root rot diseases of rubber trees. Plant Disease 71: 298–306. http://dx.doi.org/10.1094/PD-71-0298

Okane I, Srikitikulchai P, Toyama K, Læssøe T, Sivichai S, Hywel-Jones N, Nakagiri A, Potacharoen W, Suzuki KI. 2008. Study of endophytic *Xylariaceae* in Thailand: diversity and taxonomy inferred from rDNA sequence analyses with saprobes forming fruit bodies in the field. Mycoscience 49: 359–372. http://dx.doi.org/10.1007/S10267-008-0440-6

Pereira J, Rogers JD, Bezerra JL. 2010a. New *Annulohypoxylon* species from Brazil. Mycologia 102: 248–252. http://dx.doi.org/10.3852/09-116

Pereira J, Borges da Silveira RM, Trierveiler-Pereira L, Leite CL. 2010b. *Xylariales*. 160–168. in: RC Forzza et al. (eds). Catálogo de plantas e fungos do Brasil. Vol. 1. Rio de Janeiro.

Petch T. 1928. Tropical root disease fungi. Transactions of the British Mycological Society 13: 238–253. http://dx.doi.org/10.1016/S0007-1536(28)80021-0

Phosri C, Suwannasai N, Whalley AJS. 2008. The fungal distribution of *Annulohypoxylon* and *Hypoxylon* taxa found in the north of Thailand. 34th Congress of Science and Technology of Thailand. Bangkok.

Rayner RW. 1970. A mycological colour chart. Commonwealth Mycological Institute, Kew.

Rogers JD. 1979. The *Xylariaceae*: systematic, biological and evolutionary aspects. Mycologia 71: 1–42. http://dx.doi.org/10.2307/3759218

Rogers JD. 1981. Two new *Hypoxylon* species from Gabon. Canadian Journal of Botany 59: 1363–1364. http://dx.doi.org/10.1139/b81-184

Rogers JD, Ju YM. 1998. The genus *Kretzschmaria*. Mycotaxon 68: 345–393.

Saccardo PA. 1882. Sylloge pyrenomycetum. Sylloge Fungorum, vol. 1. Patavii. 766 p.

Stadler M. 2011. Importance of secondary metabolites in the *Xylariaceae* as parameters for assessment of their taxonomy, phylogeny, and functional biodiversity. Current Research in Environmental & Applied Mycology 1: 75–133. http://dx.doi.org/10.5943/cream/1/2/1

Suwannasai N, Rodtong S, Thienhirun S, Whalley AJS. 2002. Taxonomic problems of high morphological variation of *Hypoxylon* spp. in Thailand. Abstract in the RGJ-PH.D. Congress III. Chonburi, Thailand (http://forprod.forest.go.th)

Suwannasai N, Rodtong S, Thienhirun S, Whalley AJS. 2005. New species and phylogenetic relationships of *Hypoxylon* species found in Thailand inferred from the internal transcribed spacer regions of ribosomal DNA sequences. Mycotaxon 94: 303–324.

Tang AM, Jeewon R, Hyde KD. 2007. Phylogenetic relationships of *Nemania plumbea* sp. nov. and related taxa based on ribosomal ITS and RPB2 sequences. Mycological Research 111: 392–402. http://dx.doi.org/10.1016/j.mycres.2007.01.009

Thienhirun S, Whalley AJS. 2004. *Xylariaceae*. 71–77, in: EBG Jones et al. (eds). Thai Fungal Diversity. BIOTEC, Thailand.

Thienhirun S, Rodtong S, Phukhawan N, Suwannasai N. 2003. Xylariaceous fungi in Phu Hin Rongkra National Park, Thailand. Proceedings of the 2nd International Conference on Medical Mushroom. Pattaya, Thailand: 505–508.

Vasilyeva LN. 1998. Pyrenomycetes and loculoascomycetes. Lower plants, fungi, and bryophytes of the Russian Far East. Vol. IV Nauka, Sankt-Petersburg, 419 p. (in Russian).

Vasilyeva LN, Stephenson SL. 2010. Biogeographical patterns in pyrenomycetous fungi and their taxonomy. 1. The Grayan disjunction. Mycotaxon 114: 281–303. http://dx.doi.org/10.5248/114.281Not cited in the text

Vasilyeva LN, Stephenson SL 2011. Biogeographical patterns in pyrenomycetous fungi and their taxonomy. 2. Additions to the Grayan disjunction. Mycotaxon 117: 331–342. http://dx.doi.org/10.5248/117.331

Vasilyeva LN, Stephenson SL. 2014. Biogeographical patterns in pyrenomycetous fungi and their taxonomy. 4. *Hypoxylon* and the southern United States. Mycotaxon 129(1): 85–95. http://dx.doi.org/10.5248/129.85

Vasilyeva LN, Rogers JD, Miller AN. 2007. Pyrenomycetes of the Great Smoky Mountains National Park. V. *Annulohypoxylon* and *Hypoxylon* (Xylariaceae*)*. Fungal Diversity 27: 231–245.

Vasilyeva LN, Stephenson SL, Hyde KD, Bahkali AH. 2012. Some stromatic pyrenomycetous fungi from northern Thailand – 1. *Biscogniauxia*, *Camillea* and *Hypoxylon* (*Xylariaceae*). Fungal Diversity 55: 65–76. http://dx.doi.org/10.1007/s13225-011-0150-9

Vasilyeva LN, Ma HX, Stephenson SL. 2014 ["2013"]. Biogeographical patterns in pyrenomycetous fungi and their taxonomy. 3. The area around the Sea of Japan. Mycotaxon 126: 1–14. http://dx.doi.org/10.5248/126.1

Velmurugan N, Han SS, Sa DM, Lee YS. 2007. Consideration of *Hypoxylon truncatum*, based on morphological characteristics of Korean collection. Korean Journal of Electron Microscopy 37: 281–287.

Whalley AJS. 1985. The *Xylariaceae*: some ecological considerations. Sydowia 38: 369–382.

Whalley AJS. 1996. The xylariaceous way of life. Mycological Research 100: 897–922. http://dx.doi.org/10.1016/S0953-7562(96)80042-6

Whalley MA, Whalley AJS. 2007. *Ascomycota*: *Xylariales*. 95–115, in: EBG Jones et al. (eds). Malaysian Fungal Diversity. Mushroom Research Center, Malaysia.

Whalley AJS, Hywel-Jones NL, Jones EBG, Whalley MA. 1995. A preliminary account of the genera *Biscogniauxia* and *Hypoxylon* in the Chanthaburi and Chon Buri Provinces of South East Thailand. Sydowia 47: 70–81.